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Loudspeaker

The invention relates to a loudspeaker, particularly intended for use in a motor vehicle, which loudspeaker includes a housing with a front side and a rear side, a diaphragm accommodated in the housing and flexibly connected to the housing, and an actuator for displacing the diaphragm with respect to the housing along a translation axis imaginarily extending from said one side to said other side of the housing, the housing extending around the translation axis.

Patent specification EP 0 510 345 B1 discloses a loudspeaker for use in motor vehicles. The known loudspeaker comprises a conical housing, a conical frame movably supported by the housing and an electromagnetic actuator. The conical frame, at one end of which the magnet system is permanently arranged, has a predetermined breaking point which is dimensioned in such a way that it should rupture beyond a predetermined force acting on the magnet system, and the part of the frame to which the magnet system is attached should decouple from the other part of the frame. In an alternative embodiment, the conical frame of the known loudspeaker has a continuous predetermined rupture zone which, in the event of a force acting on the magnet system, should ensure that the frame telescopes concertina-fashion in the determined rupture zone.

As is generally known, safety aspects are becoming more and more important for vehicles. In this context, it can be stated that all components in a car, and thus also built-in loudspeakers, may injure the driver and passengers, if any, in the event of a crash or collision. As the number of loudspeakers mounted in a car is still ever-increasing and more and more loudspeakers in cars are positioned in the direct vicinity of the occupants, loudspeakers play an essential role in meeting current safety requirements imposed on vehicles. It has appeared that rupture points and zones applied in the conical frame of the known loudspeaker are not very reliable when it comes to meeting the above-mentioned safety requirements.

It is an object of the invention to improve the loudspeaker of the kind as defined in the preamble in such a way that it conforms to the current safety requirements imposed on speakers mounted in a motor vehicle.

According to the invention, this object is achieved with the loudspeaker which includes a housing with a front side and a rear side, a diaphragm accommodated in and flexibly connected to the housing and an actuator for displacing the diaphragm with respect to the housing along a translation axis imaginarily extending from said one side to said other side of the housing, wherein the housing extends around the translation axis and is provided with a conical forepart widening towards the front side, a base part extending towards the rear side and an intermediate housing part extending between the forepart and the base part and including transition areas connected to the forepart and the base part, which transition areas behave as hinges under the influence of an axial load above a certain value, whereby the intermediate housing portion turns towards the translation axis and the forepart turns towards the rear side under the influence of such a load. If an axial force of a certain minimum value is exerted at the front side and/or the rear side of the housing, the transition areas of the intermediate housing part deform in such a way that the intermediate housing part turns inwardly, resulting in a shortening of the housing and thus of the loudspeaker as such. If desired, the transition areas can be designed in such a way that they break after a certain bending. The mentioned axial force or load may of course also be a component of a force or load, respectively, exerted under an angle, with regard to said sides.

The actuator applied in the loudspeaker according to the invention is usually an electromagnetic actuator which is known per se. Such an actuator has a magnet system attached to the housing, particularly the base part thereof, and a so-called voice coil fixed to the diaphragm. In such a device, the housing and the magnet system are generally the most dangerous components of loudspeakers built into a vehicle, in the case of an accident.

The loudspeaker according to the invention is able to conform to contradictory requirements, viz. the requirement that it is not allowed that the magnet system comes loose from the housing and the requirement that, if during a crash or collision the loudspeaker is pressed against a human body, it is not allowed that a predetermined maximal force exerted on the human body is exceeded. It has appeared that the housing of the loudspeaker according to the invention is solid enough to prevent a disconnection of the magnet system and is weak enough to absorb sufficient energy by plastic deformation, if necessary.

In a practical embodiment of the loudspeaker according to the invention, the intermediate housing has a substantially cylindrical shape. The transition areas may have another shape, and may be e.g. curved or S-shaped.

It is not necessary that the housing of the loudspeaker according to the invention is made of only one material. Usual materials for housing are e.g. polycarbonate

and ABS (acrylnitril-butadien-styrol copolymer). By making the transition areas of another material, specific properties, such as e.g. a springback function, can be given to these areas. The housing can be manufactured by e.g. injection molding. Apart from the above-mentioned materials, suitable materials for the intermediate part are e.g. thermoplastic polyester elastomers and thermoplastic rubbers.

Alternatively, the transition areas can be formed from separate sheet materials such as rubber, rubber-plastic compounds, plastics and steel. For the above-mentioned reasons, the material of the intermediate housing part of a preferred embodiment is different from the material of the forepart and/or the base part.

Another practical embodiment has the feature that the transition areas are weaker than the other portions of the housing.

It has been proved that the following features are preferred. The forepart of the housing has an angle of inclination, related to a line parallel to the translation axis, which is at least 30 degrees. A suitable maximum value of the angle is 60 degrees. The intermediate housing part has a length dimension, viewed along a line parallel to the translation axis, which is at least 3 mm. The intermediate housing part preferably has a thickness dimension, viewed in a direction perpendicular to the translation axis, which is minimally 0.5 mm. As a rule, the thickness of the intermediate part is about 50% of the thickness of the other mentioned parts of the housing.

The invention also relates to a housing for use in the loudspeaker according to the invention. The housing according to the invention is constructed and structured as described elsewhere in this document.

It is noted in relation to the set of claims that various combinations of characteristic features defined in the claims are possible.

The above-mentioned and other aspects of the invention are apparent from and will be elucidated, by way of non-limitative examples, with reference to the embodiments described hereinafter.

In the drawings:

Fig. 1 shows an embodiment of the loudspeaker according to the invention in a diagrammatic cross-section,

Fig. 2 shows, in a cross-section, an essential part of the housing of the embodiment shown in Figure 1,

Fig. 3 shows, in a cross-section, the above-mentioned essential part after a small deformation of the housing as shown in Figure 2,

Fig. 4 shows, in a cross-section, the essential part after a large deformation.

The electrodynamic loudspeaker according to the invention, shown in Figure 1, comprises a housing 2, a translatable body 4 and an electromagnetic actuator 6. The loudspeaker has a height H and is shielded by a dust cover 5. The housing 2, which is made of ABS in this example, has a front side 2a and a rear side 2b. The housing 2 may have a more or less closed contour or may be in the form of a more open frame. The translatable body 4 comprises a three-dimensional diaphragm 8, which is situated or at least extends in the housing 2. The function of the electromagnetic actuator 6 is to displace the body 4, and thus the diaphragm 8, along a translation axis 10, being the central axis of the loudspeaker, extending from the front side 2a to the rear side 2b, or vice versa. The actuator 6 essentially comprises two elements, namely a stationary actuator element 6a which is fixed to the housing 2, and a translatable actuator element 6b which is attached to the translatable body 4. The stationary element 6a is provided with a magnet system having an annular permanent magnet 12, and the other actuator element 6b is provided with a coil system having at least one magnet coil 14. When energizing the coil 14, both actuator elements 6a, 6b magnetically co-operate with each other over an air gap 16 for generating a driving force on the translatable body 4 parallel to the translation axis 20 and hence on the diaphragm 8 forming part thereof. Said magnet system also has soft iron parts which, together with the permanent magnet 12, form a magnetic yoke defining the air gap 16. The magnet coil 14, being a cylindrical coil, also referred to as voice coil, is situated on a coil support 14a which is formed as a cylinder body being part of the translatable body 4.

The loudspeaker is provided with a flexible connection for the translatable body 4 and hence for the diaphragm 8. This flexible connection comprises a first flexible connecting means 18 proximate to the front side 2a of the housing 2 and a second flexible connecting means 20 proximate to the rear side 2b of the housing 2. The flexible connection is to ensure that the body 4, and particularly the diaphragm 8, can perform well-defined translation movements with respect to the housing 2. The first flexible connection means 18 has a flexible structure formed from, for example, a corrugated rubber annular rim which is secured, for example, glued on its outer circumference to the housing 2 and on its inner circumference to the translatable body 4. The second flexible connection means 20 is formed

as an undulating spider of, for example, textile or fabric, wherein the spider is attached to the housing 2 and to the translatable body 4.

In the further description, reference is also made to Figures 2 to 4.

In the loudspeaker according to the invention, the housing 2 is provided with a conical forepart 22a, a base part 22b and a cylindrical intermediate part 22c. The conical part 22a is positioned near the front side 2a of the housing 2 and widens toward the front side 2a. The base part 22b is located near the rear side 2b of the housing 2, may be widening towards the rear side 2b and may be strengthened by a rib structure $22b_1$. The base part 22b may be provided with mounting means $22b_2$ for mounting the loudspeaker into a case, e.g. formed by a door of a motor vehicle. The intermediate part 22c extends between the forepart 22a and the base part 22b and has transition areas $22c_1$ and $22c_2$ by means of which it is connected to the part 22a and the part 22b, respectively. These transition areas $22c_1$ and $22c_2$ are dimensioned in such a way that they function as hinges beyond a predetermined axial load (L) acting on the housing 2 and directed in a direction from the one side (2a or 2b) of the housing 2 to the other side (2b or 2a) of the housing 2. Such a load may be caused by a forward axial force F acting on the magnet system 6a of the actuator 6, while the front side 2a of the housing 2 is prevented from moving in the forward axial direction. During hinging, i.e. bending, the transitions $22c_1$ and $22c_2$, the forepart 22a and the base part 22b relatively turn to each other, in addition to which the forepart 22a simultaneously moves inwardly, i.e. towards the translation axis 10. These complex movements are demonstrated in Figures 3 and 4. As can be derived from Figure 3, which shows the core in which only a relatively small deformation of the housing has taken place, the transition $22c_1$ hinges outwardly while the transition $22c_2$ hinges inwardly. In the situation shown in Figure 4, further deformation of the transitions $22c_1$ and $22c_2$ has taken place, resulting in a considerable reduction of the original height H of the loudspeaker without the risk of causing sharp edges.

The design can be optimized and/or tuned by adapting the value w, i.e. the angle of inclination extending between the forepart 2a of the housing 2 and a line parallel to the translation axis 10, the value T, i.e. the thickness of the cylindrical intermediate part 2c, and the value L, i.e. the length of the intermediate part 2c, to the desired elastic deformation of the housing in relation to a certain load. In this context, it is noted that a certain length L is required in order to create two hinges.

It has been proved that the larger the length L, the easier the forepart of the housing can move inwardly. It has further been proved that the larger the angle w, the smaller the nominal force which is needed for bending the transitions. In other words, the housing of

the loudspeaker according to the invention can easily be designed to meet the requirements of the customers. The design is very suitable for simulations, by means of which the desired values of the above-mentioned parameters can be easily determined. The desires of the clients may be various; e.g. a customer might require a deformation of 50% under the influence of an axial force of 3000N, and another customer might require a deformation of 30% in the case of a force of 2500N at an angle of 45° with regard to the translation axis.

If desired by a client, the design can be determined in such a way that the deformations of the transitions may result in a break of a transition.

If suitable, the material of the intermediate part 2c can be chosen to be different from the material of the other parts 2a and 2b.